3.22 RADAR MODE

The two basic airborne radar types simulated in Brawler are referred to as single target track (STT) and track-while-scan (TWS). TWS antennas may be initialized in either the "OFF", "SCAN", or "TWS" state. When the initial mode is SCAN or TWS, the user specifies default patterns and positions to be used upon entering either of the other (i.e., SCAN or TWS) modes. The pilot may change the TWS pattern to select one that can enclose the greatest number of known hostile or unknown targets. The unclassified version delivered by SURVIAC does not have the TWS radar capability, so the analysis described here was limited to the STT radar type.

For STT antennas, the user specifies the initial radar disposition as either "OFF" or "SCAN". When "ON", STT radars operate in either SCAN (i.e., search) mode or STT (i.e., track) mode. Brawler calculates scores for the SCAN and STT radar modes that are used by the pilot to determine an aircraft's radar mode at all times. The decision to obtain radar lock for STT antennas is made at the pilot posture level by the conscious pilot for primary antennas or through production rules for both primary and subsidiary antennas.

A diagram of the subroutines used in radar mode selection is shown in Figure 3.22-1. The subroutine *selrdr* determines the score (value) of an STT lock on each bogey (initially, all other airborne targets are considered bad guys), the value of being in SCAN mode, and the value of being in TWS mode via calls to routines *rrsttv* and *vscan*. The subroutine *rrsttv* computes **rdrvlx** (the value of locking up on each bogey target) using the following formula:

rdrvlx = apvalx + velerr *(vdloc + rvord) + vslct + vlsbvr + vbvr + vlockd,

where:

apvalx = radar is not locked on this target and a penalty is applied for being outside the radar aperture (-15.0 to 0)

velerr = if not already locked on this target, then a penalty for elevation uncertainty (ability to place scan volume on target) (0 to 1.0). If locked on target, velerr = 1.0

vdloc = already attempting lock up on target (0 or 1.0)

rvord = pilot has been ordered to attack this target (0 or 1.0)

vslct = target has been selected in subroutine selwpn (0 or 7.0)

vlsbvr = target has been selected in subroutine selwpn and wep is semi-active or active radar missile (0 or 3.0)

vbvr = if semi-active radar missile is airborne agst this target and requires illumination (0 or 20.0)

vlockd = already locked on this target (0 to 4.0)

The subroutine *selwpn* selects the best weapon/target pair and the components **vslct** and **vlsbvr** bias the scoring towards selecting the STT lock on the target with the best weapon/target pair. Once the semi-active missile is fired, the component **vbvr** biases the scoring even more so that the STT lock is maintained. The component **vbvr** is twice the intrinsic value of the target aircraft. The documentation recommends values from 5 to 100 so that **vbvr** would then range from 10 to 200.

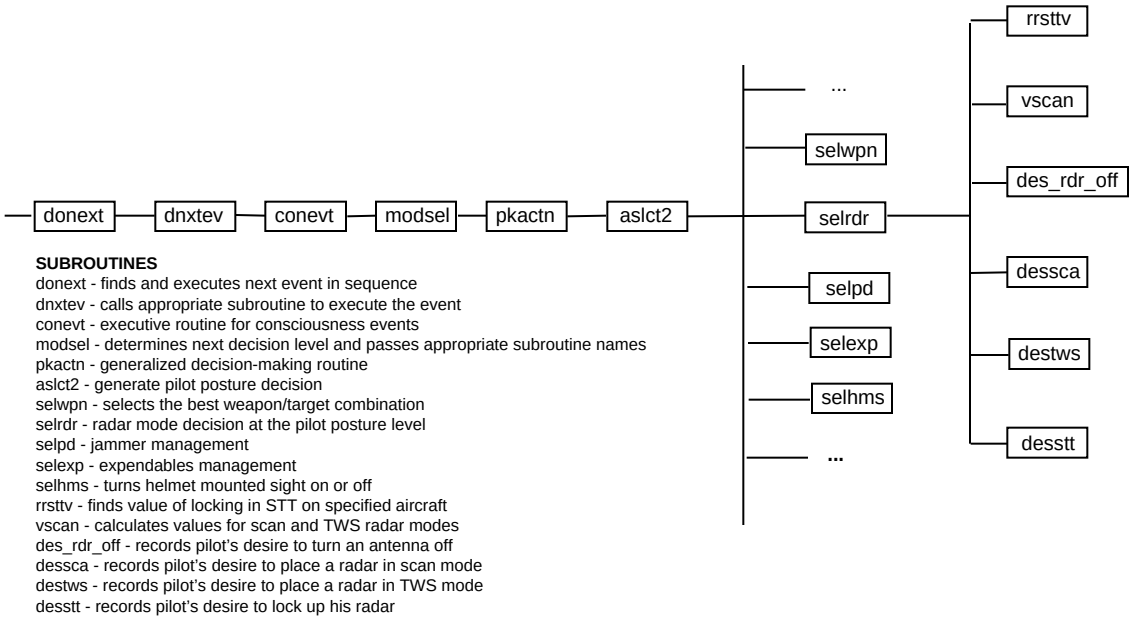


FIGURE 3.22-1. Flowchart of Radar Mode Selection.

Subroutine *vscan* is then called to compute the scores for the SCAN (**valscn**) and TWS (**valtws**) modes via the following formulae:

$$valscn = vlscan + dvinfo(mscan)$$

where:

vlscan = 20 * border (min range to hostile aircraft-max range of selected weapon, 0.5) where $0 < border < 1.0$

dvinfo = function (scan and TWS volumes, fractional information gain/loss since last update), where fractional information is based on time constant (max of 10 sec or 3 frames)

and

$$valtws = valtws + dvinfo(mtws) + dvtws$$

where:

valtws = vlscan, if antenna has TWS capability and zero otherwise

dvinfo = function (scan and TWS volumes, fractional information gain/loss since last update), where fractional information is based on time constant [(ia-dreq + 2) frames]

dvtws = (value for number of established tracks in TWS track bank) + (bias for TWS rather than STT) + (value for being already locked on hostile) + (value if ordered to attack) + (value for command guidance with penalty for missiles already in air)

Scores computed for the various target track and scan modes are stored in arrays for each target that the pilot is aware of and used to influence his decision when to change radar modes. Ignoring the more complex choices possible with TWS radars, we can examine the sensitivity to a bimodal decision of either SCAN or STT and the factors that contribute to it.

3.22.1 Objective and Procedures

The original plan was to examine effects of SCAN, STT, and TWS scores on radar mode selection decision, but the TWS objective was dropped because the classified version of the model was not available. At the FE level, the factors affecting STT and SCAN mode scores as a function of engagement constraints or conditions were examined. At the model level, the number of targets tracked and killed by radar mode per flight was postulated as an MOE, but was found to be inadequate because of the inability to compare the relative differences between STT and TWS radars. So, sensitivity of components that contribute to the STT and SCAN scores became the final objective.

A two versus one (2V1) all fighter aircraft scenario with an initial range of 35 nautical miles and all aircraft equipped with semi-active missiles and infrared missiles was set up to examine the radar mode scoring process. Production rules were not exercised in the study. An intrinsic value of 10.0 was used for each of the three aircraft:

3.22.2 Results

Table 3.22-1 is an edited subset of an IOUT file with a specific set of print commands for the selected scenario. The actions of the Red aircraft (AC3) against the two Blue aircraft (AC1 and AC2) have been listed. The EVENT DESCRIPTION column has been edited so that the actions can be understood and explained in the adjacent column. The components that make up the STT score are described in detail and can be related to the rdrvlx score using the following formula:

rdrvlx = comp7 + comp3*(comp1+ comp8) +comp4 + comp5 + comp6 + comp2

where:

comp# refers to variable in same position in previous formula version.

This example represents the sequence of events of one aircraft against two target aircraft. The situations have been selected to present an example of possible scores and their component values.

EVENT DESCRIPTION	EXPLANATION
TRANSITION 1: CURRNT TIME = 0.6039 JACID= 1 SCORE -0.593 COMPONENTS= 0.0 0.0 0.928 0.0 0.0 0.0 -0.8 0.5 JACID= 2 SCORE -0.595 COMPONENTS= 0.0 0.0 0.922 0.0 0.0 0.0 -0.8 0.5 scan: 19.931 tws: 0.000 decision for antenna 1 is SCAN MODE WPN/TGT: JTARG MSL_1 MSL_2 MSL_3 MSL_4 MSL_5 MSL_6 GUNS 1 0.00002 0.00001 0.00000 0.00000 0.00000 0.00000 0.00000 2 0.00003 0.00001 0.00000 0.00000 0.00000 0.00000 0.00000 CAN'T FIRE WPN TYPE 0 AGAINST 0 BECAUSE NO TARGET SELECTED	STT SCORE FOR AC1 (JACID=1) AND AC2 (JACID=2) COMPONENTS= COMP1 COMP2 COMP3 COMP4 COMP5 COMP6 COMP7 COMP8 SCORE= COMP7+ COMP3*(COMP1+COMP8)+COMP4+ COMP5+ COMP6+ COMP2 +AFVALZ+VELERR*(VDLOC+RVOND)+ VSLCT+VLSHVR+ VRVR + VLOCKD COMP3=0.928, if not already locked on tgt, penalty for elevation uncertainty. If locked on, +1.0 COMP7=-0.8, Radar is not locked on this tgt and a penalty is applied for being outside radar aperture COMP8=0.0, If not already attempting to lock on tgt, otherwise 1.0 SCAN SCORE TWS = 0 SINCE NO TWS MODE IN UNCLASSIFIED TAC BRAWLER RADAR MODE BASED ON MAX OF STT, SCAN, TWS SCORES WPN/TGT PAIR VALUES MAX VALUE IS BEST WPN/TGT PAIR BEST WPN/TGT PAIR IS MSL1/AC1
TRANSITION 2: CURRNT TIME = 36.2781 JACID= 1 SCORE -0.565 COMPONENTS= 0.0 0.0 0.851 0.0 0.0 0.0 -0.8 0.5 JACID= 2 SCORE 9.414 COMPONENTS= 0.0 0.0 0.842 7.0 3.0 0.0 -0.8 0.5 scan: 2.118 tws: 0.000 decision for antenna 1 is STT LOCK ON 2 WPN/TGT: JTARG MSL_1 MSL_2 MSL_3 MSL_4 MSL_5 MSL_6 GUNS 1 0.00021 0.00014 0.00000 0.00000 0.00000 0.00000 0.00000 2 0.00026 0.00018 0.00000 0.00000 0.00000 0.00000 0.00000 CAN'T FIRE WPN TYPE 1 AGAINST 2 BECAUSE SWITCHOLOGY	COMP2=0.0, If not already locked on this tgt, otherwise 4.0 COMP4=7.0, Tgt is best wpn/tgt pair COMP5=3.0, Tgt is best wpn/tgt pair and wpn is semi-active radar missile COMP7=-0.8, Radar is not locked on this tgt and a penalty is applied for being outside radar aperture COMP8=0.0, If not ordered to attack this tgt, otherwise 1.0 COMP6=0.0, If illumination for airborne semi-active radar missile agst this tgt is not required BEST WPN/TGT PAIR IS MSL1/AC2
TRANSITION 3: CURRNT TIME = 45.3854 JACID= 1 SCORE -0.575 COMPONENTS= 0.0 0.0 0.758 0.0 0.0 0.0 -0.8 0.5 JACID= 2 SCORE 14.000 COMPONENTS= 0.0 4.0 1.000 7.0 3.0 0.0 0.0 0.5 scan: 0.344 tws: 0.000 decision for antenna 1 is STT LOCK ON 2 WPN/TGT: JTARG MSL_1 MSL_2 MSL_3 MSL_4 MSL_5 MSL_6 GUNS 1 0.00154 0.00054 0.00000 0.00000 0.00000 0.00000 0.00000 2 0.00487 0.00044 0.00000 0.00000 0.00000 0.00000 0.00000 CAN'T FIRE WPN TYPE 1 AGAINST 2 BECAUSE TGT NOT IN ENV	COMP2=4.0, Already locked on tgt, otherwise zero COMP3=1.0, if not already locked on tgt, penalty for elevation uncertainty. If locked on, +1.0 COMP4=7.0, Tgt is best wpn/tgt pair COMP5=3.0, Tgt is best wpn/tgt pair and wpn is semi-active radar missile BEST WPN/TGT PAIR IS MSL1/AC2
TRANSITION 4: CURRNT TIME = 77.5954 JACID= 1 SCORE -0.547 COMPONENTS= 0.0 0.0 0.298 0.0 0.0 0.0 -0.5 0.0 JACID= 2 SCORE 34.000 COMPONENTS= 0.0 4.0 1.000 7.0 3.0 20.0 0.0 0.0 scan: 0.148 tws: 0.000 decision for antenna 1 is STT LOCK ON 2 WPN/TGT: JTARG MSL_1 MSL_2 MSL_3 MSL_4 MSL_5 MSL_6 GUNS 1 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 2 0.04082 0.00346 0.00000 0.00000 0.00000 0.00000 0.00000 ILLUMINATE RADAR MISSILE TARGET(S) CAN'T FIRE WPN TYPE 1 AGAINST 2 BECAUSE MISL COMING OFF RAIL	FIRED SEMI-ACTIVE RADAR MISSILE AT 2 AT 76.595 COMP2=4.0, Already locked on tgt COMP3=1.0, if not already locked on tgt, penalty for elevation uncertainty. If locked on, +1.0 COMP4=7.0, Tgt is best wpn/tgt pair COMP5=3.0, Tgt is best wpn/tgt pair and wpn is semi-active radar missile COMP6=20.0, Semi-active radar missile is airborne agst this tgt and requires illumination COMP8=2*(Intrinsic value of tgt aircraft-ID for fighters,40 for bombers, and 80 for AWACS) BEST WPN/TGT PAIR IS MSL1/AC2

EVENT DESCRIPTION	EXPLANATION
TRANSITION 5: CONRVT TIME = 90.3528 JACID= 1 SCORE -0.447 COMPONENTS= 0.0 0.0 0.220 0.0 0.0 0.0 -0.7 1.0 JACID= 2 SCORE 34.000 COMPONENTS= 0.0 4.0 1.000 7.0 3.0 20.0 0.0 0.0 scan: 0.170 tws: 0.000 decision for antenna 1 is STT LOCK ON 2 WPN/TGT: JTRRG MSL_1 MSL_2 MSL_3 MSL_4 MSL_5 MSL_6 GUNS 1 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 2 0.08073 0.08375 0.00000 0.00000 0.00000 0.00000 0.00000 CAN'T FIRE WPN TYPE 1 AGAINST 2 BECAUSE TGT NOT IN ENV	BEST WPN/TGT PAIR IS MSL1/AC2
TRANSITION 6: CONRVT TIME = 91.3528 JACID= 1 SCORE -0.553 COMPONENTS= 0.0 0.0 0.211 0.0 0.0 0.0 -0.8 1.0 JACID= 2 SCORE 31.000 COMPONENTS= 0.0 4.0 1.000 7.0 0.0 20.0 0.0 0.0 scan: 0.215 tws: 0.000 decision for antenna 1 is STT LOCK ON 2 WPN/TGT: JTRRG MSL_1 MSL_2 MSL_3 MSL_4 MSL_5 MSL_6 GUNS 1 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 0.00000 2 0.08617 0.10240 0.00000 0.00000 0.00000 0.00000 0.00000 CAN'T FIRE WPN TYPE 2 AGAINST 2 BECAUSE SWITCHOLOGY	COMP2=4.0; Already locked on tgt COMP3=1.0; if not already locked on tgt, penalty for elevation uncertainty. If locked on, =1.0 COMP4=7.0; Tgt is best wpn/tgt pair COMP5=0.0; Tgt is best wpn/tgt pair but wpn is IR missile COMP6=20.0; Semi-active radar missile is airborne agst this tgt and requires illumination BEST WPN/TGT PAIR CHANGED TO MSL2/AC2
TRANSITION 7: CONRVT TIME = 98.3528 JACID= 1 SCORE -1.808 COMPONENTS= 0.0 0.0 0.178 7.0 0.0 0.0 -9.0 1.0 JACID= 2 SCORE -3.088 COMPONENTS= 0.0 0.0 0.152 0.0 0.0 0.0 -3.1 0.0 scan: 0.214 tws: 0.000 decision for antenna 1 is SCAN MODE WPN/TGT: JTRRG MSL_1 MSL_2 MSL_3 MSL_4 MSL_5 MSL_6 GUNS 1 1.74697 3.41871 0.00000 0.00000 0.00000 0.00000 0.00000 2 0.05111 0.12775 0.00000 0.00000 0.00000 0.00000 0.00000 CAN'T FIRE WPN TYPE 2 AGAINST 1 BECAUSE SWITCHOLOGY	COMP4=7.0; Tgt is best wpn/tgt pair COMP3=0.152; if not already locked on tgt, penalty for elevation uncertainty. If locked on, =1.0 COMP7=-3.1, Radar is not locked on this tgt and a penalty is applied for being outside radar aperture BEST WPN/TGT PAIR CHANGED TO MSL2/AC1
TRANSITION 8: CONRVT TIME = 99.3528 JACID= 1 SCORE -2.193 COMPONENTS= 0.0 0.0 0.177 7.0 0.0 0.0 -9.4 1.0 JACID= 2 SCORE -3.598 COMPONENTS= 0.0 0.0 0.150 0.0 0.0 0.0 -3.6 0.0 scan: 0.212 tws: 0.000 decision for antenna 1 is SCAN MODE WPN/TGT: JTRRG MSL_1 MSL_2 MSL_3 MSL_4 MSL_5 MSL_6 GUNS 1 1.75245 4.40481 0.00000 0.00000 0.00000 0.00000 0.00000 2 0.05311 0.12819 0.00000 0.00000 0.00000 0.00000 0.00000 CAN'T FIRE WPN TYPE 2 AGAINST 1 BECAUSE SWITCHOLOGY	COMP4=7.0; Tgt is best wpn/tgt pair COMP7=-9.4, Radar is not locked on this tgt and large penalty for being outside radar aperture COMP8=1.0; Pilot has been ordered to attack this tgt, otherwise zero BEST WPN/TGT PAIR IS MSL2/AC1
TRANSITION 9: CONRVT TIME = 100.3528 JACID= 1 SCORE 5.380 COMPONENTS= 0.0 0.0 0.181 7.0 0.0 0.0 -1.8 1.0 JACID= 2 SCORE -0.991 COMPONENTS= 0.0 0.0 0.148 0.0 0.0 0.0 -1.0 0.0 scan: 0.211 tws: 0.000 decision for antenna 1 is STT LOCK ON 1 WPN/TGT: JTRRG MSL_1 MSL_2 MSL_3 MSL_4 MSL_5 MSL_6 GUNS 1 1.79992 4.72741 0.00000 0.00000 0.00000 0.00000 0.00000 2 0.07821 0.19190 0.00000 0.00000 0.00000 0.00000 0.00000 CAN'T FIRE WPN TYPE 2 AGAINST 1 BECAUSE TGT NOT IN ENV RDR_TO_STT...AC 1 ANT 1 ATTEMPTING LOCK ON 1 AT TIME = 100.553 Earliest lock-up time = 101.553	COMP7=-1.8, Radar is not locked on this tgt and small penalty for being outside radar aperture COMP4=7.0; Tgt is best wpn/tgt pair BEST WPN/TGT PAIR IS MSL2/AC1 Attempting lock on 1

EVENT DESCRIPTION	EXPLANATION
TRANSITION IO: CONEVT TIME = 101.3528	
JACID= 1 SCORE -3.576 COMPONENTS= 1.0 0.0 0.193 7.0 0.0 0.0 -11.0 1.0	COMP1=1.0, Already attempting to lock on tgt
JACID= 2 SCORE -10.798 COMPONENTS= 0.0 0.0 0.148 0.0 0.0 0.0 -10.8 0.0	COMP7=-11.0, Radar is not locked on this tgt and large penalty for being outside radar aperture
scan: 0.310 trr:: 0.000	
decision for antenna 1 is SCAN MODE	
WPN/TGT: JTARG MSL_1 MSL_2 MSL_3 MSL_4 MSL_5 MSL_6 GUNS	
1 1.98583 4.88543 0.00000 0.00000 0.00000 0.00000 0.00000	BEST WPN/TGT PAIR IS MSL2/AC1
2 0.07870 0.20051 0.00000 0.00000 0.00000 0.00000 0.00000	
CAN'T FIRE WPN TYPE 2 AGAINST 1 BECAUSE TGT NOT IN ENV	KILLED AT 102.334

Figure 3.22-2 is a graphical presentation of AC3's STT scores by components against AC2. The component 'comb' is the combined entity represented by: 'velerr*(vdloc + rvord)'. The other comp scores shown in the figure are from the components listed on the left side of Table 3.22-1. There is an event number across the bottom for each transition in Table 3.22-1. The actions corresponding to the transition points are described below:

1	time = 0.6039	targets are outside radar aperture and radar is in scan mode
2	time = 36.2782	target 2 is selected for attack and wpn is semi-active radar missile.
3	time = 45.3854	radar locked on target 2
4	time = 77.5954	fired semi-active missile at a/c 2 which requires illumination.
5	time = 90.3528	fired semi-active missile at a/c 2 which requires illumination.
6	time = 91.3528	IR missile is selected and it does not require support.
7	time = 98.3528	targets are outside radar aperture and radar is in scan mode.
8	time = 99.3528	radar in scan mode.
9	time = 100.3528	attempting lock on target 1.
10	time = 101.3528	targets are outside radar aperture and radar is in scan mode

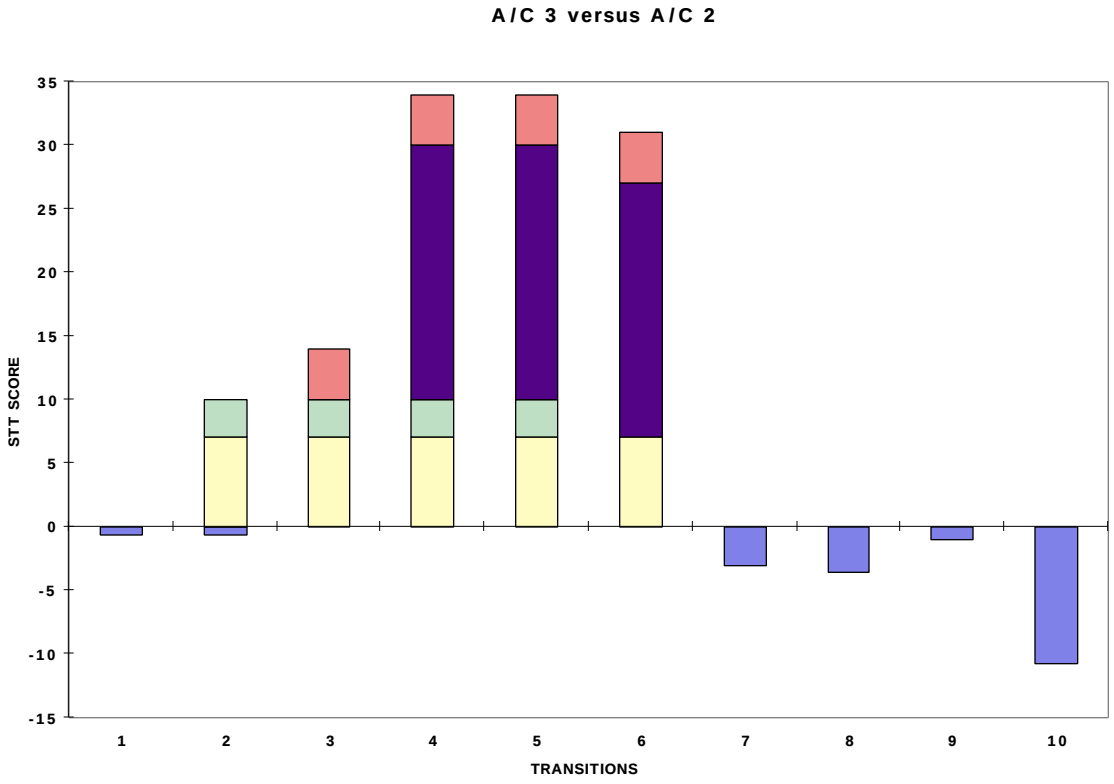
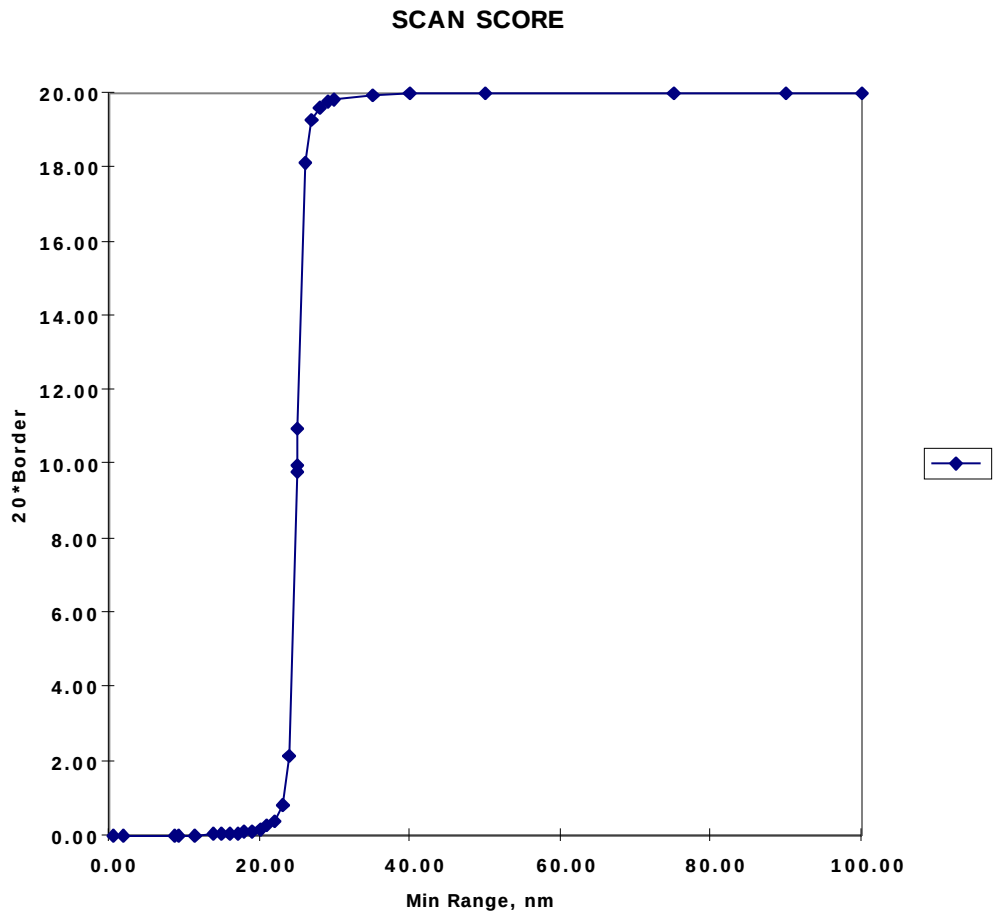


FIGURE 3.22-2. Graphical Presentation of AC3's STT Scores by Components Against AC2.

For a missile with a maximum range of 24.95 nautical miles, the value of vlscan goes from near zero to 20.0 as the minimum range to the hostile aircraft goes from near zero to 100 nautical miles. (See Figure 3) When the minimum range is 24.95, the value of vlscan is approximately 10.0. Dvinfo is less than 1.0 and so valscn is less than 1.0 when the minimum range is less than 23 nautical miles. According to the documentation, the value

of the scan score is primarily a function of range to hostiles. At long ranges the score is always very high. At shorter ranges, the score has been tailored so that it exceeds the STT lock score when the target is still at least ten seconds from presenting a firing opportunity. The plan is to stay in scan mode to gather information on other aircraft for as long as possible.



vlscan = 20*border(min range to hostile - 24.95, 0.5)

valscn = vlscan + dvinfo(mscan), 0 < valscn < 20.0

FIGURE 3.22-3.

As the unclassified version of Tac Brawler does not have the TWS radar mode, **valtws** = 0 always. The maximum of the values of the STT locks and scan mode determines the desired radar mode. Vlscan is greater than zero, so that the scan mode is selected whenever the STT lock scores are negative. Valscn is the scan score and valtws is the tws score referred to in Table 3.22-1. The choices are 'ANTENNA OFF', 'STT LOCK ON specific aircraft', or 'SCAN MODE'. The subroutine selrdr processes the mode selection. If the desired mode, STT target, pattern, pattern position, or PRF control mode is different from the current setting, it also sets the appropriate radar switch change event. (See Figure 3.21-4) When a target has been selected in selwpn, it's STT lock score becomes the maximum and STT lock on the target is the selected radar mode.

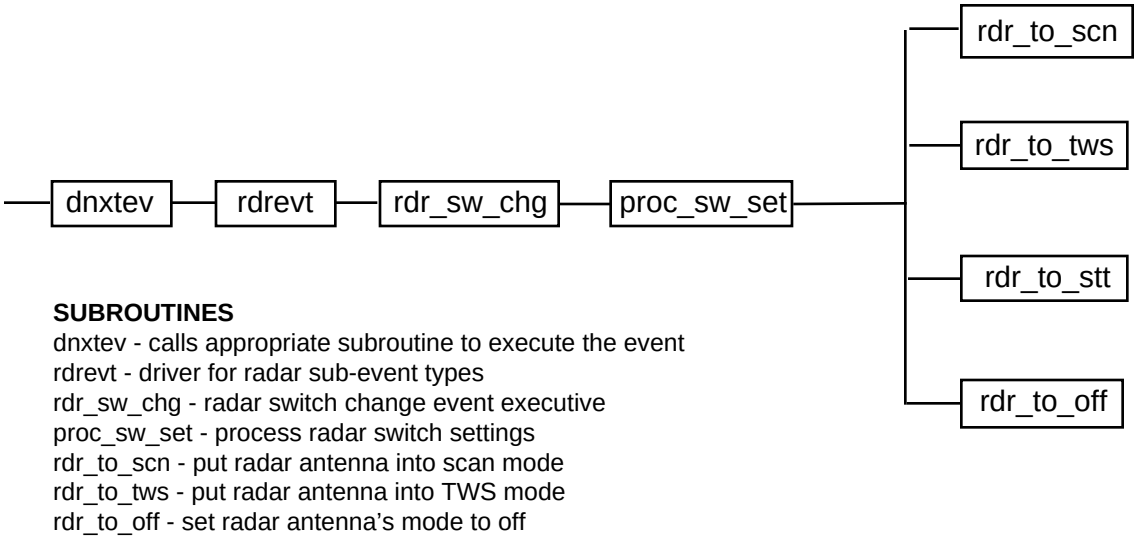


FIGURE 3.22-4. Flowchart of Radar Switch Changes.

Figure 3.22-5 is similar to Figure 3.22-2 and displays the scores of AC3 against AC1. Figure 3.22-6 is a plot of AC3's scores (STT against AC1, STT against AC2, and SCAN) for the events in Table 3.22-1. The maximum score determines the radar mode for AC3. At Transition point 1, the radar mode is 'SCAN', but changes to 'STT lock on AC2 at point 2. The radar mode changes to 'SCAN' at point 7, switches to 'STT lock on AC1 at point 9, and back to 'SCAN' at point 10. Refer to Table 3.22-1 for more details.

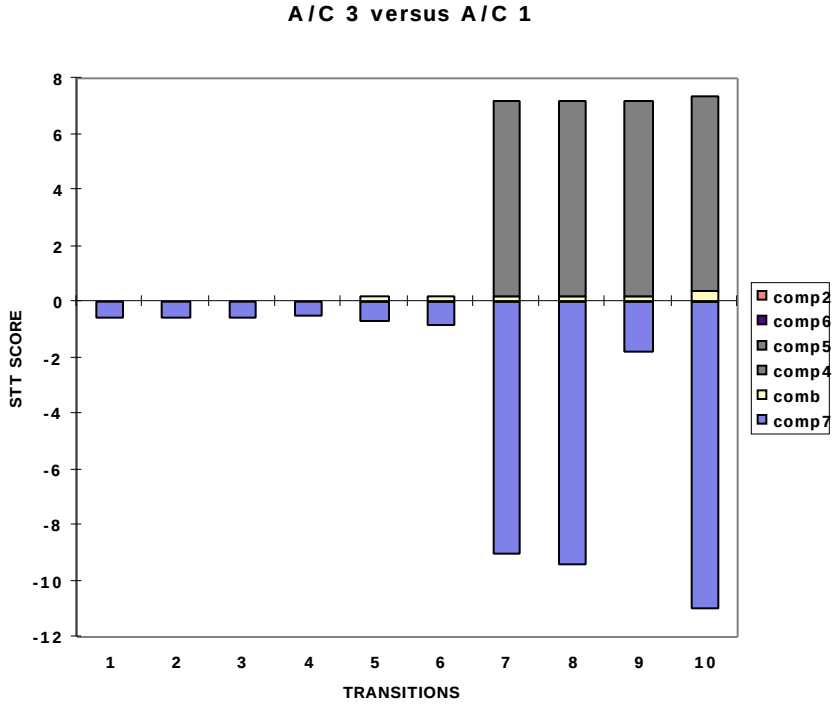


FIGURE 3.22-5.

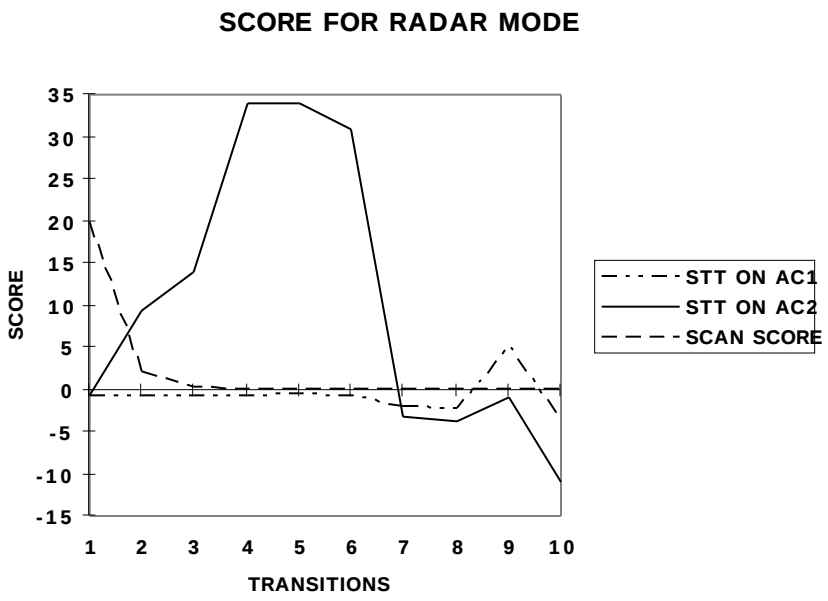


FIGURE 3.22-6.

3.22.3 Conclusion

The preceding paragraphs have described the scoring of the radar modes and the selection of the radar mode by the simulation. For the unclassified version of Tac Brawler, there is no TWS radar mode and so the example scenario only referred to the scan and STT modes. The examination of the effect of the scan and STT mode scores on the radar selection decision at the model level by the number of targets tracked and killed by radar mode does not apply. The pilot detects targets while in the scan mode and once the radar locks up on a specific target (STT mode), only that target is swept. No other targets may be detected by the radar while it is locked. The semi-active radar missile requires an STT lock on the target aircraft to guide on until impact.